Status of BTeV

Talk for PAC Teleconference
June 16, 2004
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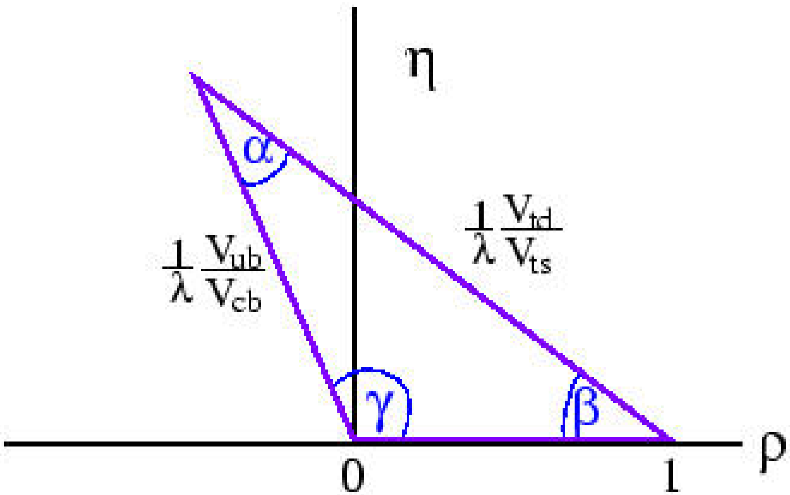
Outline

- The Evolving Physics Case
- Detector Layout and Key Design Features
- Recent Developments from Reviews Past
- The staged schedule
- LHCb/BTeV Startup issues
- Current Project Scope
  - C0 Outfitting
  - C0 Interaction Region
  - BTeV Detector
- Technical Issues
  - Interaction region
  - Pixel Detector
- Test Beam Activities and Plans
- Commissioning Issues
- Conclusion

The Evolving Physics Case

- Emphasis now is on New Physics (NP) Beyond the Standard Model (BSM)
  - Standard Model Constraints on CP violation and rare decays are very specific
  - There is a reasonable subset of decays that are theoretically clean I.e. negligible or manageable theoretical uncertainties
  - New Physics scenarios almost all have additional freedom in the flavor sector, such as new phases, that can modify the SM picture
- New Physics could be seen for the first time in B decays or, what is now considered more likely, **as new physics is found at the Tevatron and LHC, the implications for B physics of various explanations can be worked out and looked for. B physics can help to resolve what many feel will be a complicated picture. B physics may permit one to eliminate some interpretations and to pin down the parameters of others. In particular, B physics is sensitive to new phases.**

Key Measurements of the CKM matrix in B Decays



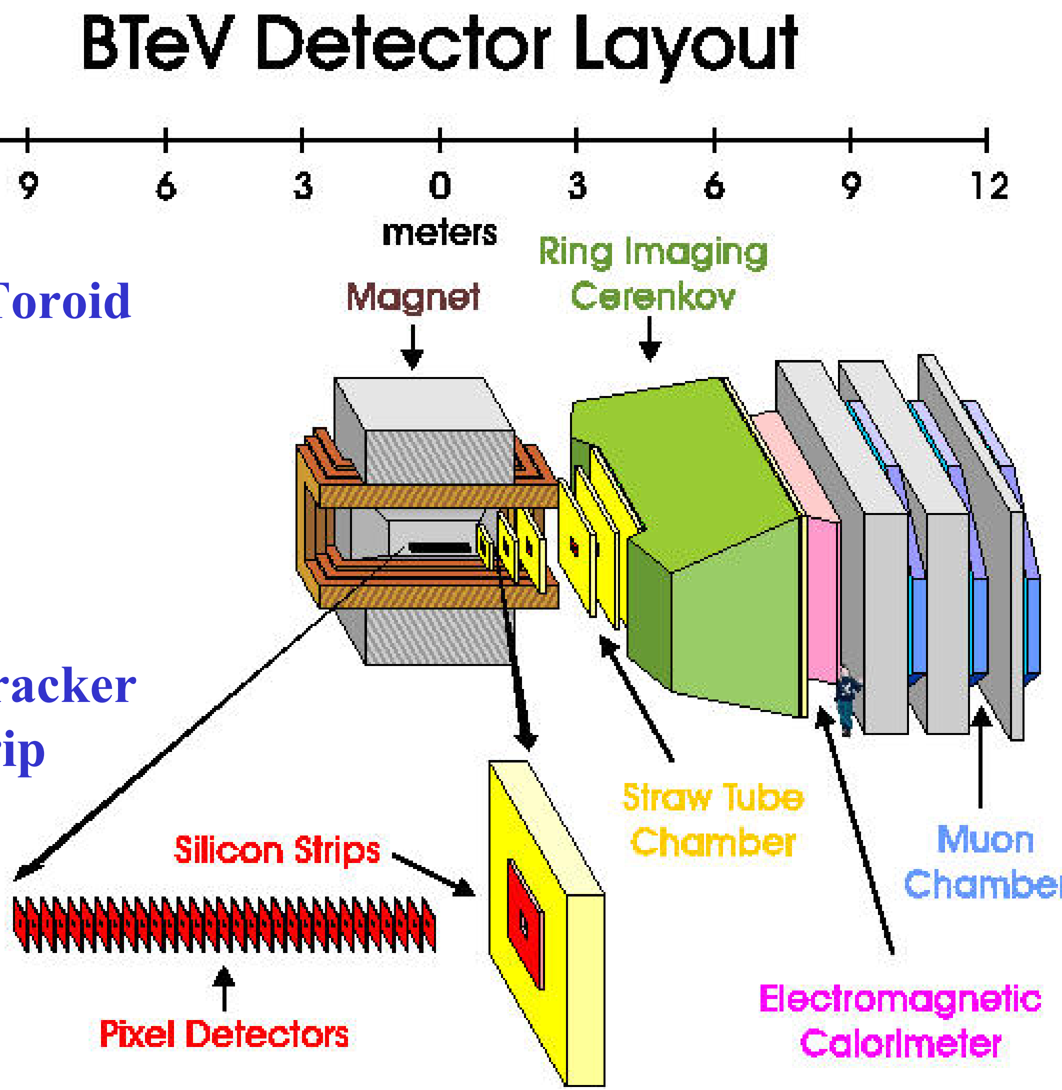
$$\chi = \arg\left(-\frac{V_{cs}^{*}V_{cb}}{V_{ts}^{*}V_{tb}}\right)$$

Physics Quantity	Decay Mode
$\sin(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$
$\cos(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$
$\mathrm{sign}(\sin(2\alpha))$	$B^o \to \rho\pi, B^o \to \pi^+\pi^-$
$\sin(\gamma)$	$B_s \to D_s K^-$
$\sin(\gamma)$	$B^+ \to D^o K^+$
$\sin(\gamma)$	$B \to K\pi$
$\sin(\gamma)$	$B \to \pi^+\pi^-, B_s \to K^+K^-$
$\sin(2\chi)$	$B_s \to J/\psi\eta', J/\psi\eta$
$\sin(2\beta)$	$B^o \to J/\psi K_s$
$\sin(2\beta)$	$B^o \to \phi K_s, \eta' K_s, J/\psi\phi$
$\cos(2\beta)$	$B^o \to J/\psi K^*, B_s \to J/\psi\phi$
x_s	$B_s \to D_s\pi^-$
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\eta', K^+K^-, D_s\pi^-$

About 1/2 of the key measurements are in B_s decays. About 1/2 of the key measurements have π^o's or γ's in the final state!

BTeV addresses these issues.

BTeV Detector



1.1 Vertex Detector, Toroid and Beam Pipe
1.2 Pixel Detector
1.3 RICH
1.4 EMCAL
1.5 Muon Detector
1.6 Forward Straw Tracker
1.7 Forward Microstrip tracker
1.8 Trigger
1.9 Data Acquisition
1.10 Integration

Key Design Features of BTeV

- A **dipole located ON the IR gives BTeV a spectrometer covering the forward antiproton rapidity region.**
- A precision vertex detector based on **planar pixel arrays**
- A **vertex trigger at Level I** which makes BTeV especially efficient for states that have only hadrons. The tracking system design has to be tied closely to the trigger design to achieve this.
- Strong particle identification based on a **Ring Imaging Cerenkov counter.** Many states emerge from background only if this capability exists. It enables use of charged kaon tagging.
- **A lead tungstate electromagnetic calorimeter for photon and π^0 reconstruction.**
- A very **high capacity data acquisition system** which frees us from making excessively restrictive choices at the trigger level

BTEV / C0

This Year in Review

- P5

"P5 supports the construction of BTeV as an important project in the world-wide quark flavor physics area. Subject to constraints within the HEP budget, we strongly recommend an earlier BTeV construction profile and enhanced C0 optics."

- Office of Science 20-Year Facilities Report

Priority: 12 Near Term – Important, Ready

BTeV

What's New: BTeV will use state-of-the-art detector technologies and the very high particle production rates at Fermilab's Tevatron to obtain the large samples of B-particles needed to make the necessary measurements.

- DOE Critical Decision 0 (CD-0)

CD-0, Approve Mission Need
for the
BTeV Project
at Fermi National Accelerator Laboratory

"We were informed the BTeV CD-0 has been approved by Ray Orbach on Feb. 17"

From the CD-1 Lehman Review

- The summary recommendations from the Lehman CD-1 review
  - "The committee concluded that the technical scope and cost estimate are ready for CD-1; however the schedule will require additional effort. The committee supported the proposed technical scope. Most of the systems are technically sound and will likely meet the performance specifications."
  - "Develop a schedule and funding profile for BTeV, such that the desired scientific capabilities are obtained while ensuring that the scientific output is competitive and timely. Provide revised plans to DOE as soon as possible, to support the CD-1 decision process."

Changes to the Schedule

- Staged Installation of the Detector: The detector will be installed in two stages
  - The first stage will be installed in a shutdown from August1, 2009 to November 30, 2009. That will be followed by a 7 month run.
  - The second stage will be installed in a shutdown beginning in early July of 2010 and lasting 3 months until Sept. 30, 2010.
- Impact of Additional Resources: forward funding from Syracuse University, contribution of of $7.5M from INFN
- Reallocation of Resources within the Project
- Adoption of Explicit Recommendations and Suggestions from the Review
- Effect of More Work on Specific Issues Raised in the Review
- More Total Time for Installation
- Scrubbing of the whole Schedule

Staging - I

- Stage 1 (August 1 – Nov 30, 2009): **An Excellent Detector - 75% of full detector's capability for B's decaying into all-charged final states and 50-60% of the full detector's capability for B's decaying into final states containing photons**
- There is a run from Nov 30, 2009 to end of June 2010.The first month will be used for commissioning the IR, followed by detector commissioning and then data-taking
- Stage 2 (July 1 –Sept 30,2010): All remaining elements of the Liquid RICH, EMCAL, forward tracker and Muon Detector installed in C0. Trigger and DAQ components can be installed in the Counting Room as they arrive in 2009 and early 2010. When running resumes, we will have the full BTeV detector.

Staging - II

- The Staged Installation achieves four key goals
  - Provides much more "float" since 2009 budget authority can produce results that have significant float with respect to the second installation stage.
  - Provides significantly more time for installation – 30 weeks vs 17 in the schedule presented at the CD-1 Review
  - Provides additional safety margin for Lead Tungstate Crystals in case their arrival is delayed by CMS' problems
  - Provides a fully competitive, indeed superior , detector with respect to LHCb on schedule in 2009 (discussed in talk by Sheldon Stone).

Beginning in August 2009 when Run 2 ends, the Tevatron schedule will be set based on BTeV's needs.

BTeV/ LHCb Startup Issues

- LHC has an uncertain schedule. Issues are not just related to first collisions but also
  - when backgrounds are reduced to an acceptable level
  - When overall reliability and consistency of machine operations, including interference with CMS and ATLAS, is achieved
  - What inefficiencies will occur to tune for higher luminosity and problems associated with hotter beams going through detector than needed for LHCb
- As the luminosity is increased for CMS and ATLAS, , LHCb will have much hotter beams passing through its IR than needed to supply its luminosity and may suffer from serious backgrounds.

BTeV/ LHCb Startup Issues

- The Tevatron should be reasonably well understood. BTeV is not asking for more luminosity than is likely to be achieved in Run II. Recent progress is very reassuring.
  - We will be the primary user, which should give us a big advantage in commissioning and in steady running
  - We will have the benefit of many years of improvements to the control of beams for experiments and an understanding of how to control backgrounds
  - We will be able to control the luminosity so we can have a steady plan of advancing from low luminosity to higher luminosity as we learn about the detector
  - We can use the ability to put in large or small stores to plan a sequence of studies and corrective accesses that will be much harder for LHCb to do

IR: Current Status

- Mike Church, Accelerator Division,is in charge of IR subProject. Jim Kerby of the Technical Division is in charge of Magnet Production part.
- P5 approved BTeV without a custom IR, but Fermilab decided to implement a custom IR based on LHC quadrupoles. This gives BTeV more luminosity and physics reach.
- The project has a WBS, a cost estimate, a schedule and an Advanced Conceptual Design Report that will evolve into TDRs
- Internal Review of the IR was held on Feb 18, 19

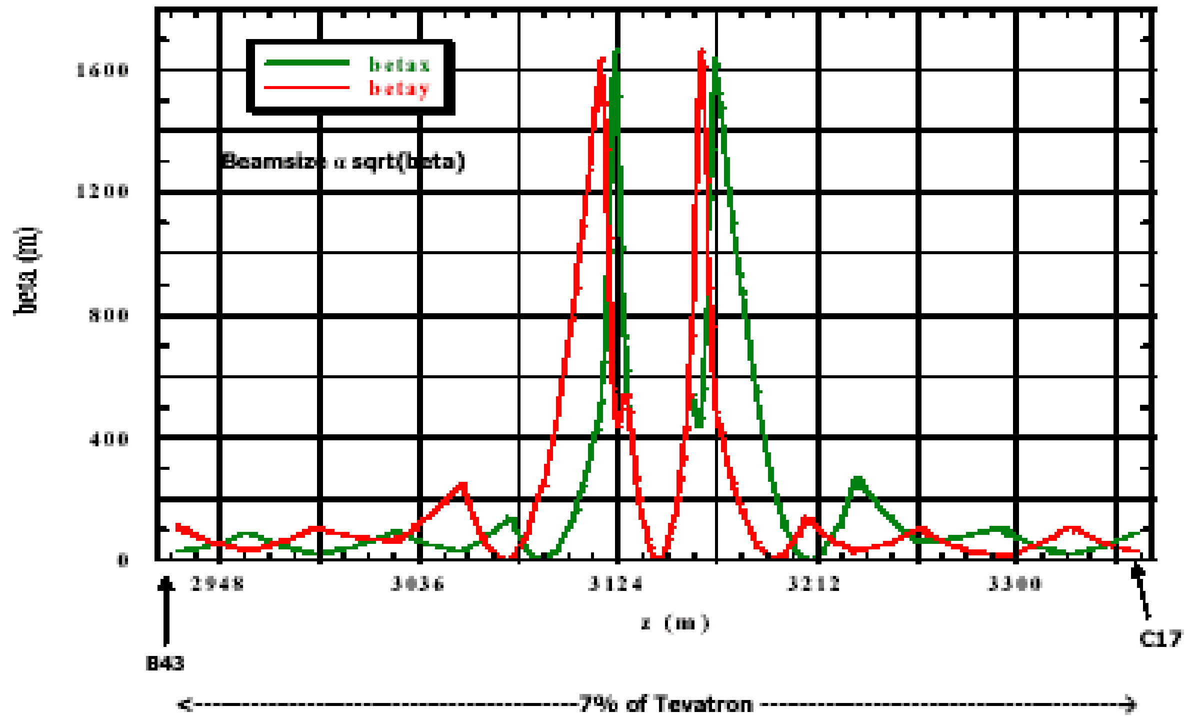
This design produces a β^* of 35 cm, same as at B0 and D0. BTeV luminosity will be the same as at B0/D0 when BTeV begins to run in 2009ish.

Results of Internal Review of the IR

- "A conceptual design report (CDR) for the BTeV Interaction Region (IR) has been written. This CDR sets forth the requirements for meeting these requirements. It presents the accelerator physics and beam optics design for the IR and addresses the conceptual design for the superconducting magnets and correctors, and cryogenic systems, vacuum systems, controls, and beam instrumentation required to support the new BTeV low beta interaction region. **The conceptual design is judged to be a reasonable basis for proceeding to the more detailed design for the IR."**
- **"The accelerator physics design has progressed to the stage that it can be "frozen" and considered the basis for component selection and component design decisions. Additional work on tracking is desirable"**

Design

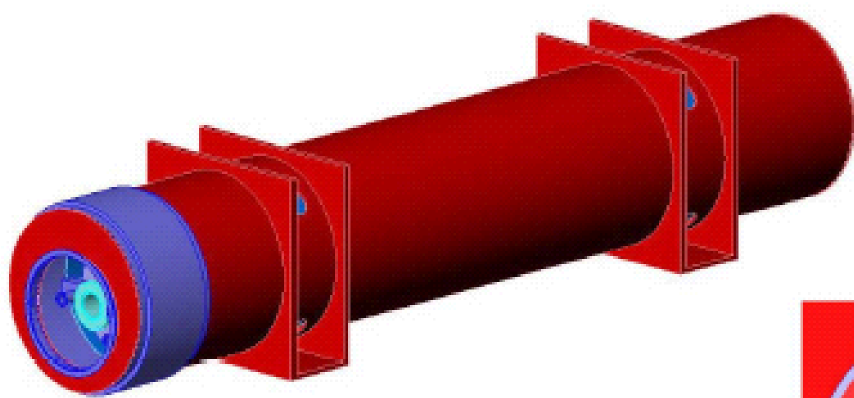
C0 Low Beta Lattice (in perspective)



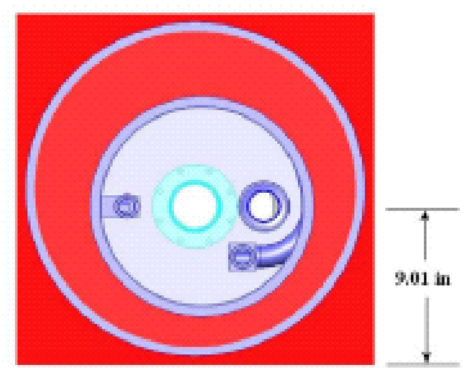
New development: β* now same as CDF/D0 (35cm) and not 50cm as before. **The Luminosity in BTeV will be the same as it is in CDF at the end of Run 2**

BTeV Low-Beta Quad

LB Quad



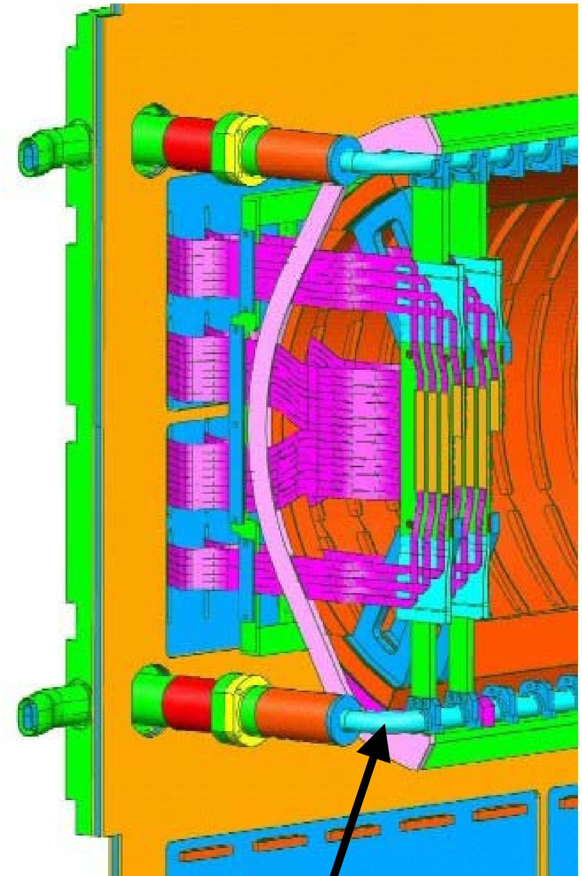
Courtesy T. Nicol



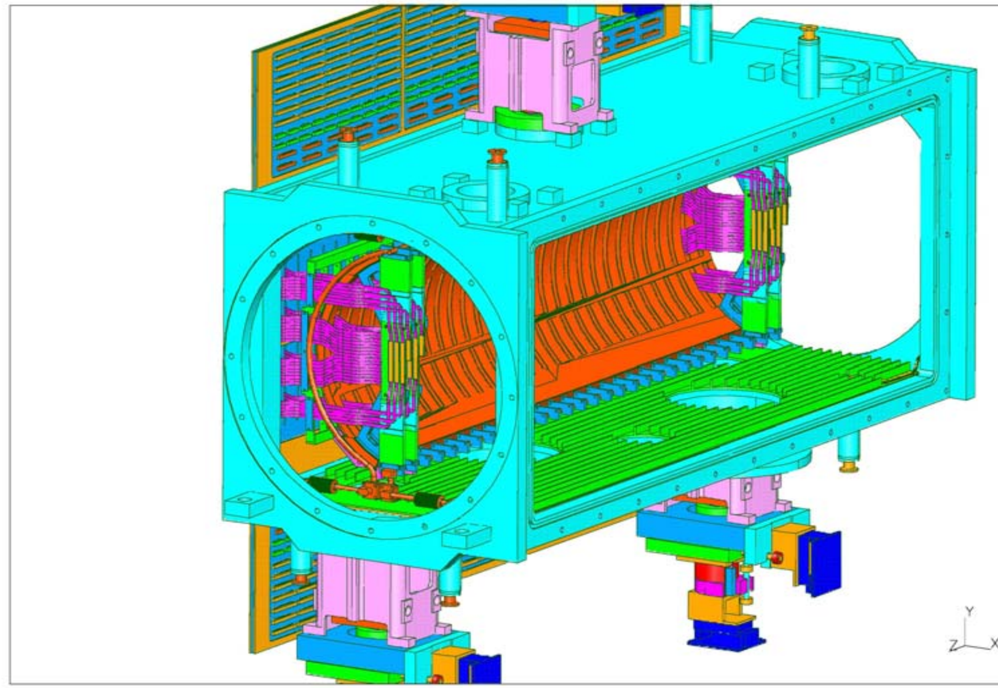
This is a conceptual design of the LHC Low Beta Quad. repackaged with a smaller cryostat so it fits in the TeV beam tunnel.

Pixel Detector Assembly

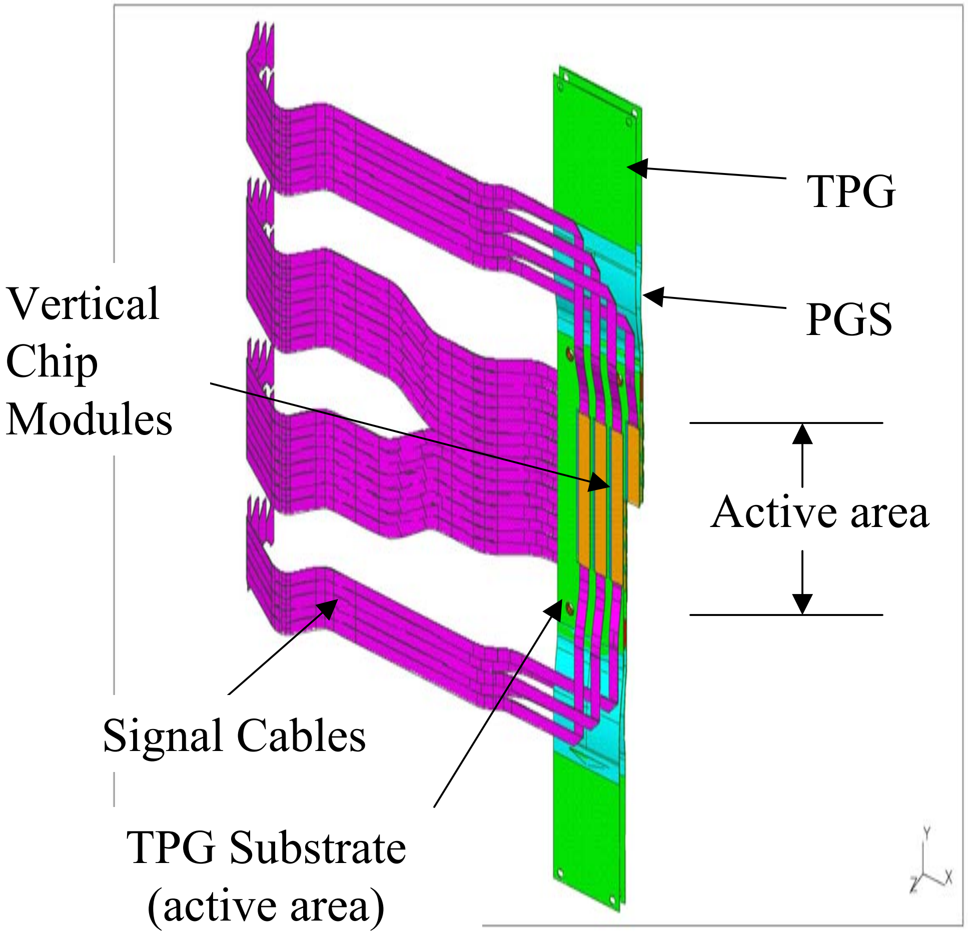
- Detector placed inside the vacuum vessel
- Detector assembled in 2 halves



Stainless steel cooling pipes

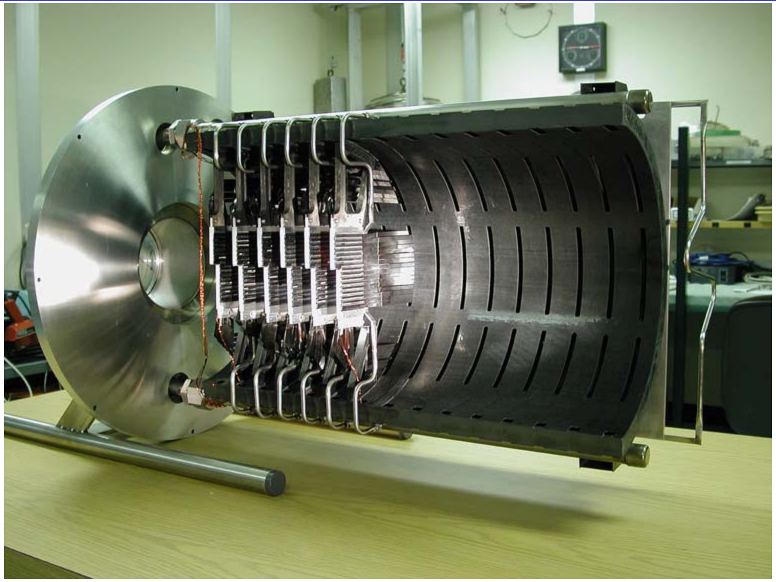


Half-station Configuration

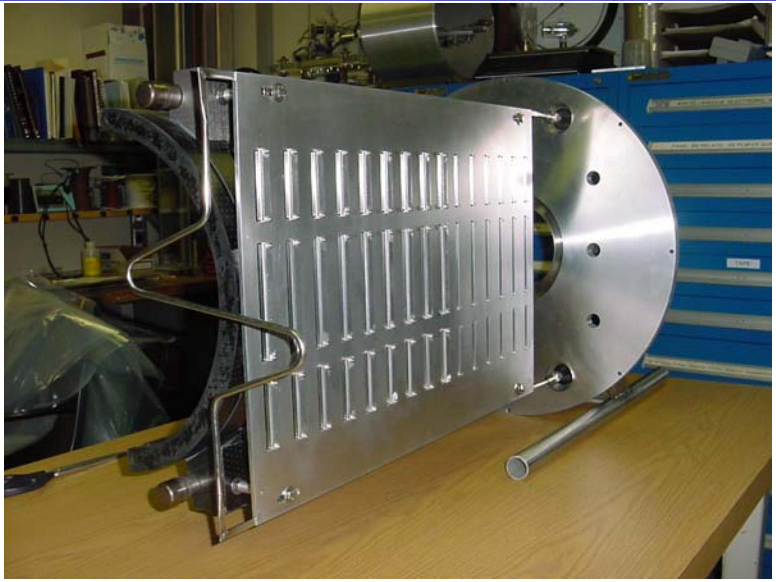


- Substrate is made up of Thermal Pyrolytic Graphite (TPG) & Pyrolytic Graphite Sheet (PGS)
  - Processed >1000°C
  - TPG 1700 W-m/K in-plane
  - PGS 600–800 W-m/K in-plane
- Material is minimized by using the higher thermal conductivity of TPG and PGS in combination with a large temperature gradient from the cooling tube to the active area
- Flexible PGS section provides compliance between the cooling tubes and the active area
- A heater just outside the active area maintains the average operating temperature from station to station independent of readout chip power.

5% Model Outgassing Test



6 substrates with dummy modules (10% of pixel stations)



Cable support / Heat sink (10% of full scale)

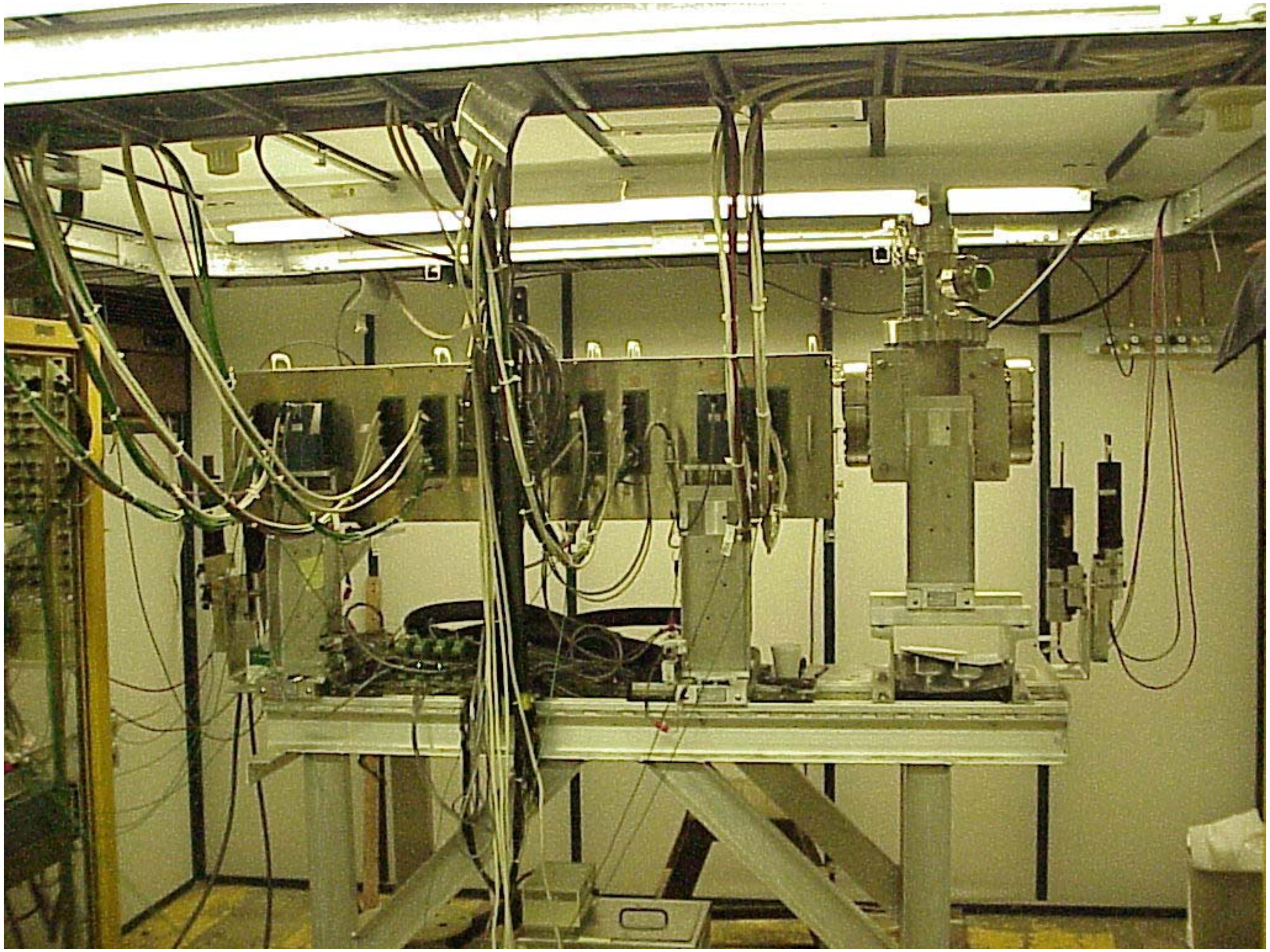
- Model ~5% of detector components that contribute to outgassing
- Gas load measurement 5×10^{-4} torr-L/sec due to outgassing room temperature
- Majority of gas load is water
- ~1% of gas load is N_2
- Pressure 9×10^{-9} torr with heat sink –165°C, pixels at –10°C

BTeV R&D Highlights and Plans

- Pixel Detector: achieved design (5-10 micron) resolution in 1999 FNAL test beam run. Demonstrated radiation hardness in exposures at IUCF. **Will have a test of almost final sensor and readout chip in FNAL test-beam, MTEST, in 2004- starting now.**
- Straw Detector: prototype built, **has been tested at FNAL in 2004,**
- **EMCAL: four runs at IHEP/Protvino demonstrated resolution and radiation hardness and verified stability of calibration system. We would eventually like to be doing some EMCAL beam tests at FNAL and are beginning to set up the equipment in MTEST now**
- RICH: HPD developed and tested. MAPMT is being bench tested. **Full test cell is at FNAL and is being set up in MTEST now. This will permit direct comparison of HPD and MAPMT.**
- Muon system tested in 1999 FNAL test beam run. Better shielding from noise implemented and bench-tested. **Design to be finalized in FNAL test starting now.**
- Silicon strip electrical and mechanical design well underway. **Prototype front end to be tested in summer/fall 2004**

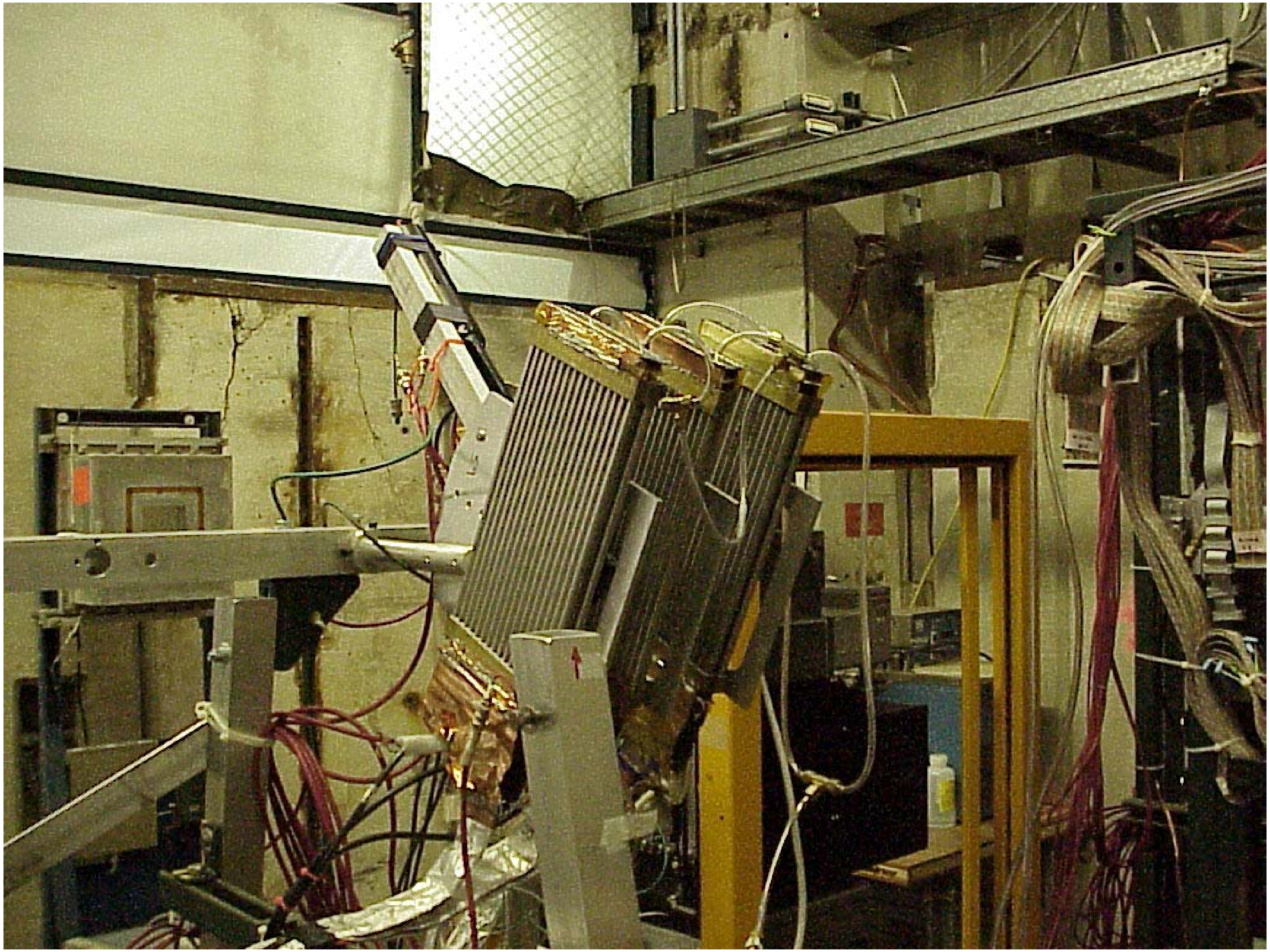
Work supported by DOE/FNAL, DOE/University Program, NSF, INFN, IHEP, and others.

External View of Pixel Telescope Test Box

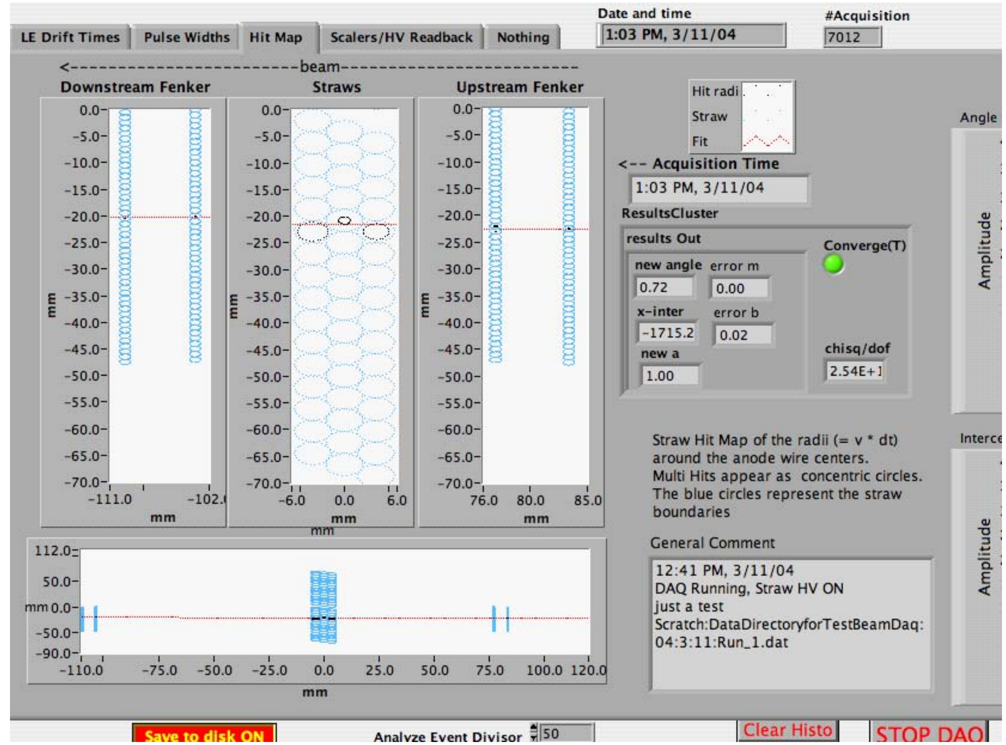


RICH Test Setup in MTEST

Muon Planks ready for Testing in MTEST



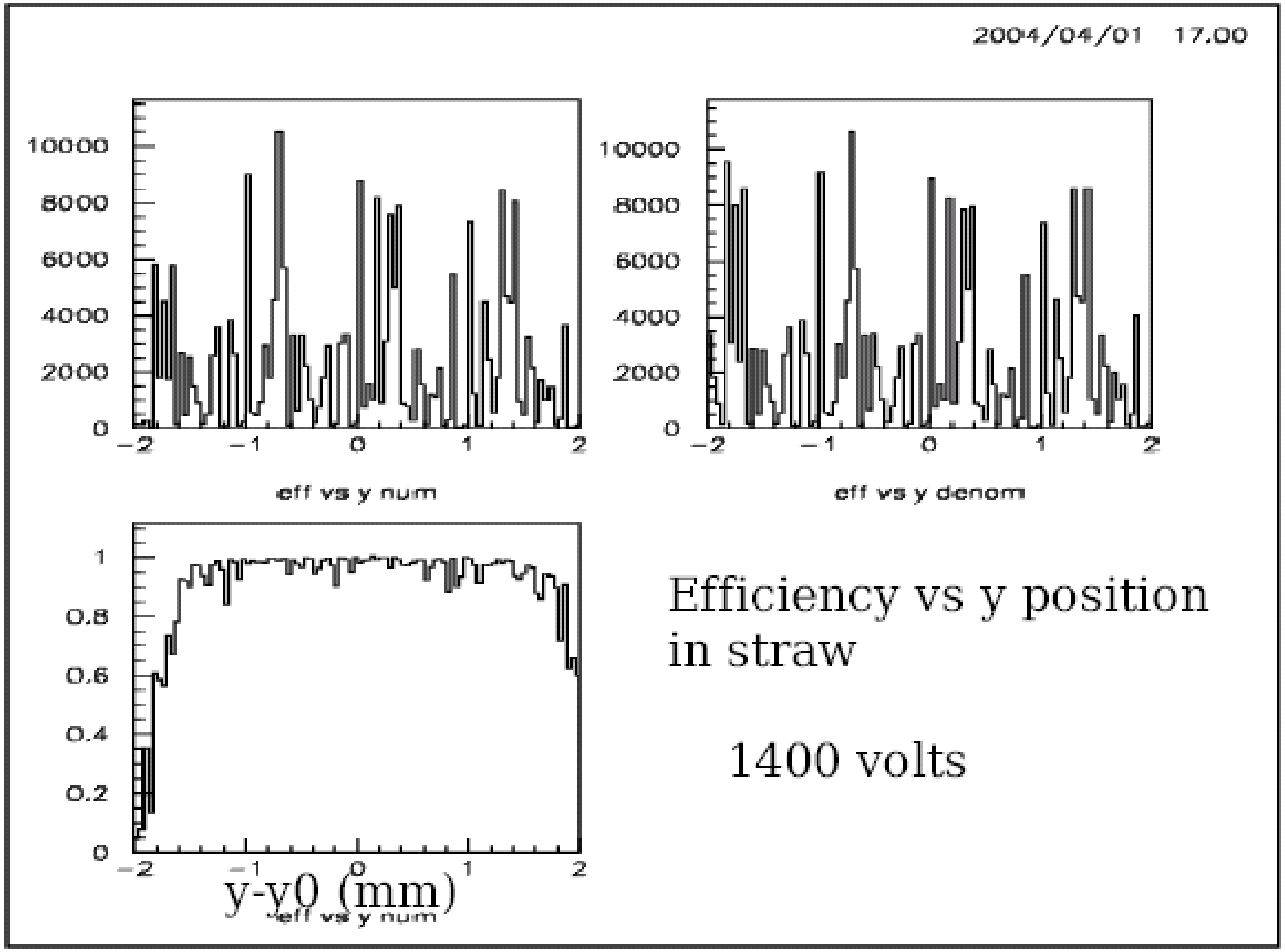
Straw Setup in MTEST

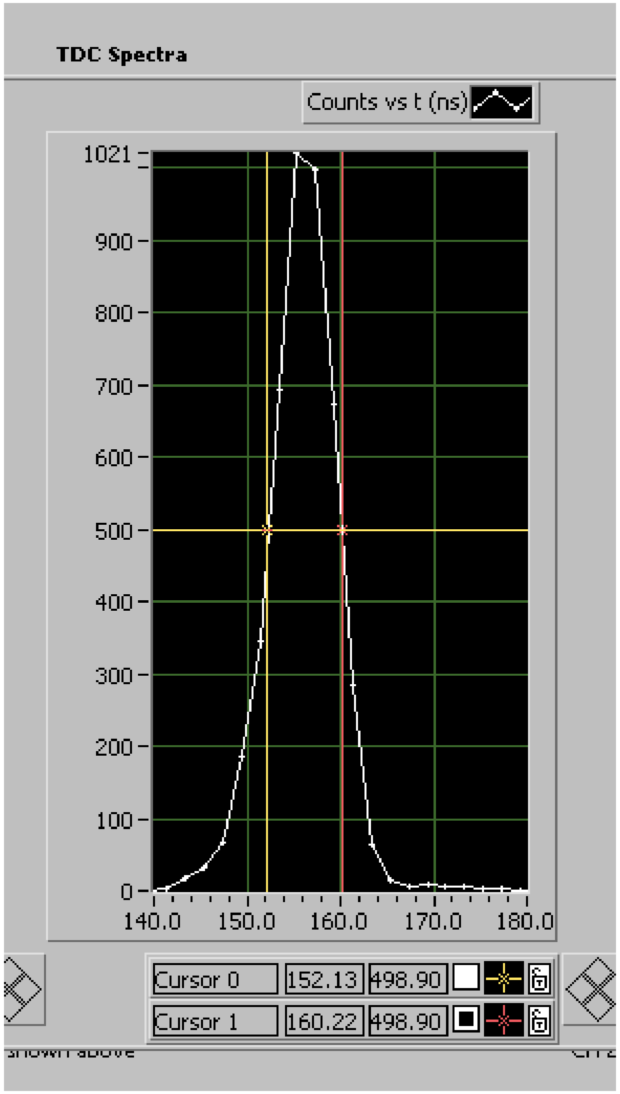


96 Straw module

Tracks recorded in
MT Slow Extracted Beam

Efficiency Plot for Straws





TDC Spectrum from previous Slide.
FWHM = 8.1 ns => 486 μ.
RMS = 206 μ.
MWPC position resolution =144 μ.
Quadrature Subtraction gives
<u>Straw Resolution =148 μ</u>.

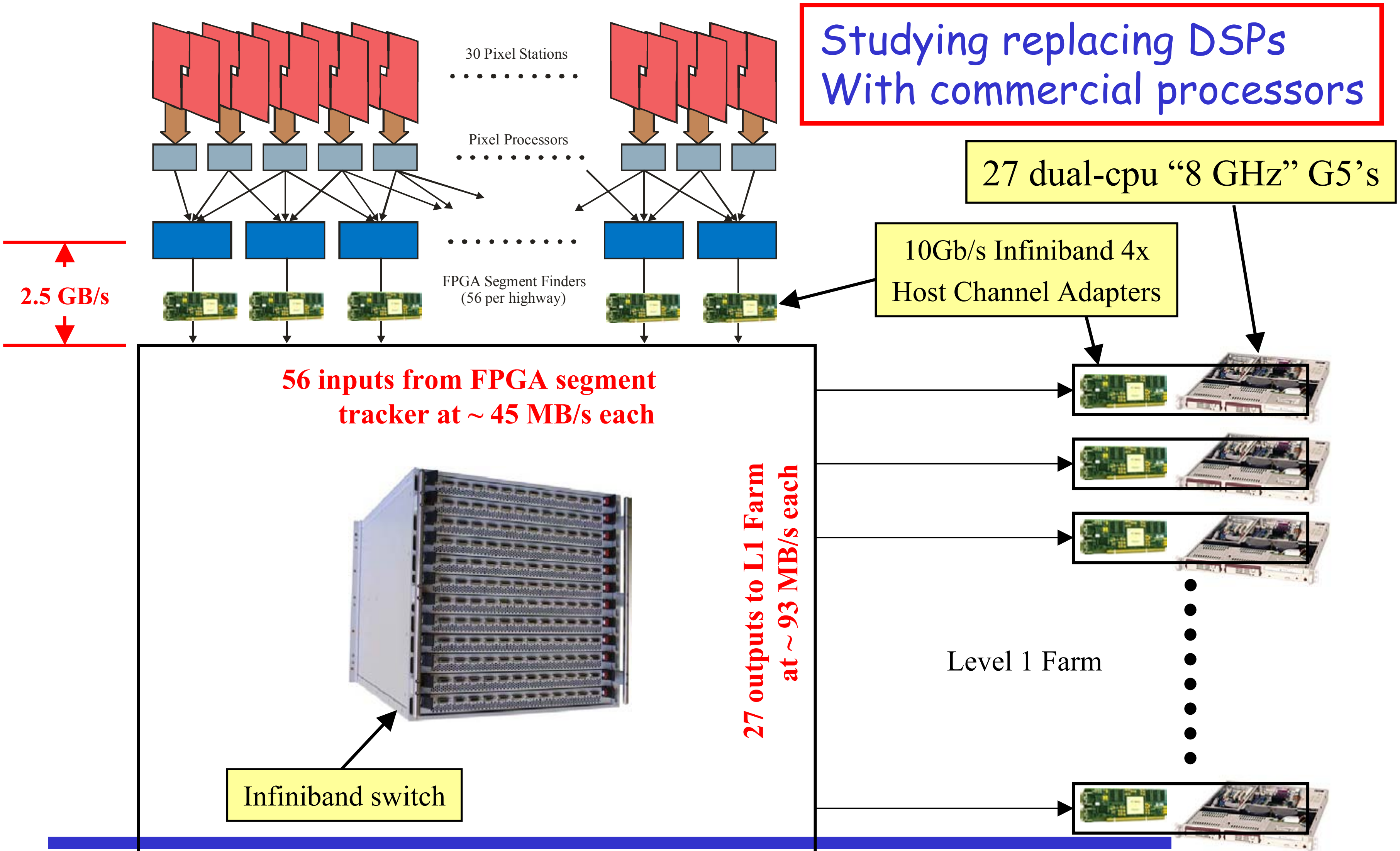
This meets the needs for BTeV Forward Tracking.

Radiation Hardness and Aging: There have been many studies using sources that say all will be well. We want to test straws in a hadron environment at IUCF to be sure.

EMCAL

- There have been four runs to study the EMCAL at Protvino, under the leadership of our IHEP colleagues. In these runs they have
  - Established that we can get the required energy and position resolution
  - Studied the radiation damage properties of the crystals in hadron environments, including the damage mechanism and the recovery properties
  - Studied in detail calibration methods that will be used to maintain the performance of the detector
  - Studied crystals made by 4 different suppliers
- We plan to keep test setups at Protvino and to recreate it in MTEST

Conceptual design for 1 trigger highway using commodity processors:



Commissioning

- Our excellent R&D program and the ability to run detectors in the test beam for long periods of time, eventually with near final electronics and software, should help us prepare for a rapid commissioning
- We will be able to run some detectors in C0 using collisions at the end of stores as early as 2008.
- We have an all-digital trigger so that we should be able to test it thoroughly before the beam comes. We are using the extra time available to us to improve and simplify the design
- We already have established a beam halo task force with AD and are studying all the various machine backgrounds both by simulation and by capturing the experience of CDF and D0. We should not be facing a wholly new situation with respect to backgrounds and machine upsets.

Conclusions

- We are making excellent technical progress on the detector, C0 outfitting and C0 IR
- We will succeed in this round of reviews, finish the remaining R&D in '04, and get started on final design and construction in calendar '05.
- We are learning invaluable lessons from our test beam experiences that should help us commission the detector rapidly
- BTeV is an experiment that can keep the domestic program engaged in TeV scale physics after the LHC turns on. It complements our involvement in the LHC program. It uses a machine in which we will have made a huge investment and in which progress has been very impressive. BTeV can do great physics and can do much for the US and Fermilab program.